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JET STREAMS OVER THE BRITISH ISLES DURING JUNE 14–18, 1951

By R. MURRAY, M.A.

Summary.—It is shown that the strong upper flow over the British Isles during the period June 14–18, 1951, was associated with two distinct jet streams, although both existed together for only a short time. Both jet streams occurred on the forward side of a major long-wave trough, and apparently in association with the same generalized frontal zone of a cold front. The lateral movement of the jet streams is shown to have been roughly related to the geostrophic advection at the surface perpendicular to the jet-stream axis. The nature of the tropopause and variations in the height and intensity of the jet-stream axes are discussed.

Introduction.—Inspection of the upper air charts for the period June 14–18, 1951, when a strong SW. air flow existed in the upper troposphere over the British Isles, showed that a single wind maximum occurred on June 14, 16, 17 and 18, but the position was uncertain on June 15 owing to the apparently erratic variations in wind speed reported by several of the aerological stations. This paper attempts to describe and explain the pattern of behaviour of the wind field during this five-day period, and shows that two distinct jet streams actually co-existed for a time on June 15, 1951. The period analysed afforded a good opportunity for the examination of certain questions connected with jet streams. One is concerned with the lateral movement of a jet stream; another is the nature of the tropopause near and especially on the low-pressure side of a jet stream; yet another is the variation of the height of a jet-stream axis along its length.

The wind and temperature fields were investigated with the help of cross-sections drawn at six-hourly intervals from 0900 G.M.T., June 14 to 1500 G.M.T., June 18, 1951. For most of the period the section shown on the charts of the first four days of the period illustrated in Fig. 1 was employed; this section utilized upper air observations from some or all of the stations, Stornoway, Aldergrove, Liverpool, Larkhill, Trappes and Lyons. The main flow backed somewhat during June 18 so that a rather differently orientated section was used at 0900 and 1500 G.M.T. on that day (see Fig. 1). The sectional analysis ceased with the movement of the jet stream away from England over the Continent later on June 18.

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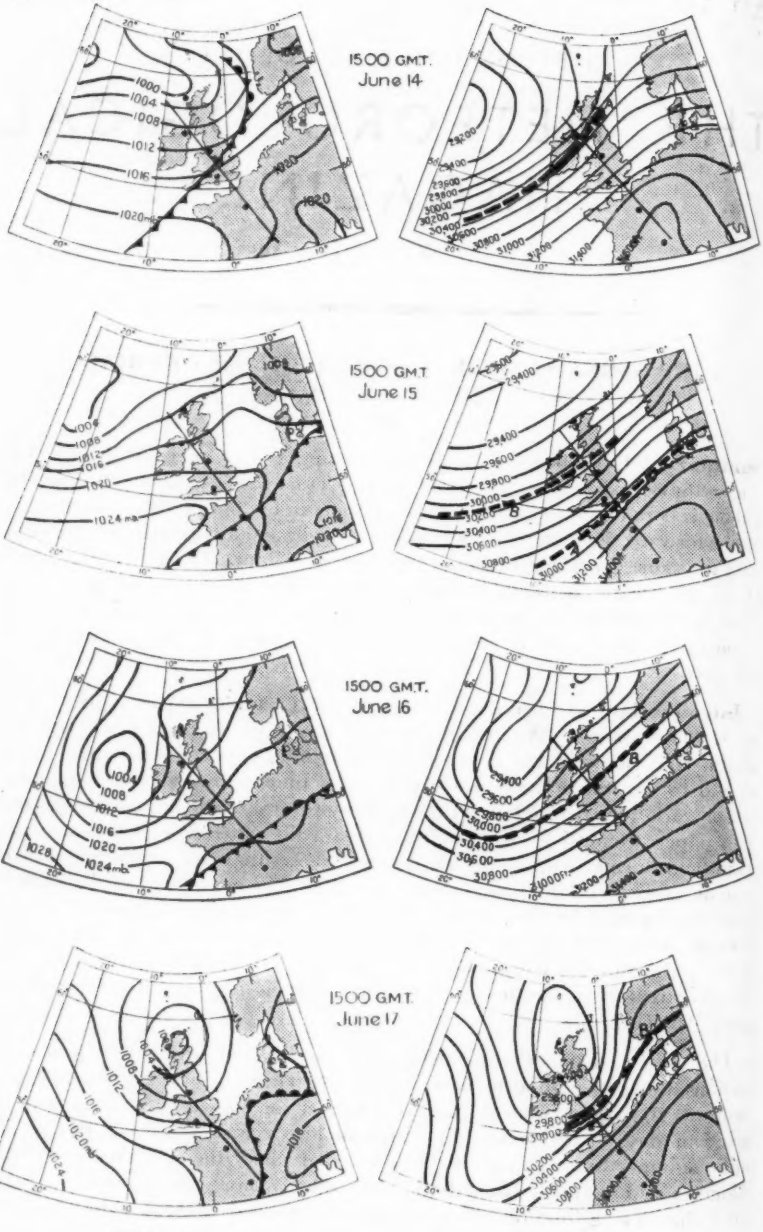
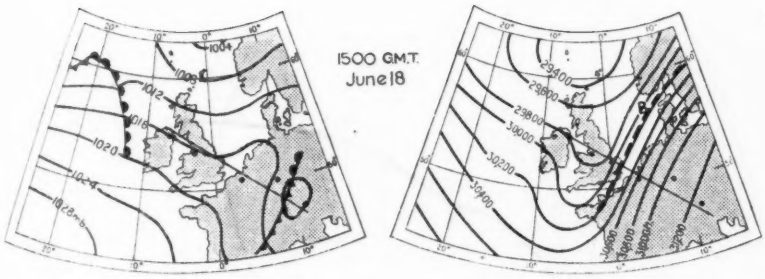


Surface charts

300-mb. charts

FIG. 1—SURFACE AND 300-MB. SYNOPTIC CHARTS, JUNE 14–18, 1951



Surface chart 300-mb. chart

FIG. 1—*continued*

Synoptic situation.—The general synoptic developments may be followed by means of Fig. 1 which shows the surface and 300-mb. maps daily at 1500 G.M.T. A depression moved north-east some 200 miles off north-west Scotland on June 14. Its cold front crossed England as a weak katafront[1] and reached northern France about midnight on June 14; for the next four days the surface front over France and Germany was often ill defined, but broadly associated with a belt of shallow lows and some thundery outbreaks rather typical of summer weather over the Continent. A minor trough swept east across Scotland some 200–300 miles behind the primary front, but without having any obvious effect on either the pressure or the weather of England. Meanwhile, during June 14, cyclogenesis occurred some 200 miles south of Iceland in the elongated trough extension from the depression off north-west Scotland. This new centre, after about 24 hours of consolidation *in situ*, moved 300 miles southwards, then turned east and was near north-west Ireland at midnight on June 16; thereafter it travelled steadily north-east across north Scotland. A cyclonic vortex also formed at 300 mb. on June 14 and subsequently followed much the same track. The cold trough to the south of the upper low moved east at the average rate of five degrees longitude per day, reaching the British Isles on June 18 in a form sharper than existed previously; this cold trough was essentially a long-wave feature in the westerlies.

Movement and behaviour of the jet streams.—The jet-stream picture can be seen from sections shown in Figs. 2–6. A single wind maximum, A, just under the tropopause is shown in Fig. 2 (1500 G.M.T., June 14); it moved south and is shown just north of Larkhill in Fig. 3 (0900 G.M.T., June 15). However, a second wind maximum, B, appeared for the first time north of Aldergrove; this new wind maximum is not shown by direct wind observations, but is based on geostrophic wind computations made with a scale similar to that described by Matthewman[2]. Fig. 4 (1500 G.M.T., June 15) shows wind maximum B, as a major feature, well substantiated by wind reports in addition to geostrophic computations, while wind maximum A is shown as a weakening system south of Larkhill. At 2100 G.M.T., June 15, wind maximum B was situated south of Aldergrove and wind maximum A over France and Germany (a section from Jever to Munich located wind maximum A south of Jever with indications of another wind maximum to the north of Jever). By 0300 G.M.T. on June 16 wind maximum B was just north of Liverpool, with A only a weak residual centre south of Trappes. Henceforth only wind maximum B existed; Fig. 5 (1500 G.M.T., June 16) and Fig. 6 (1500 G.M.T., June 18) are typical sections.

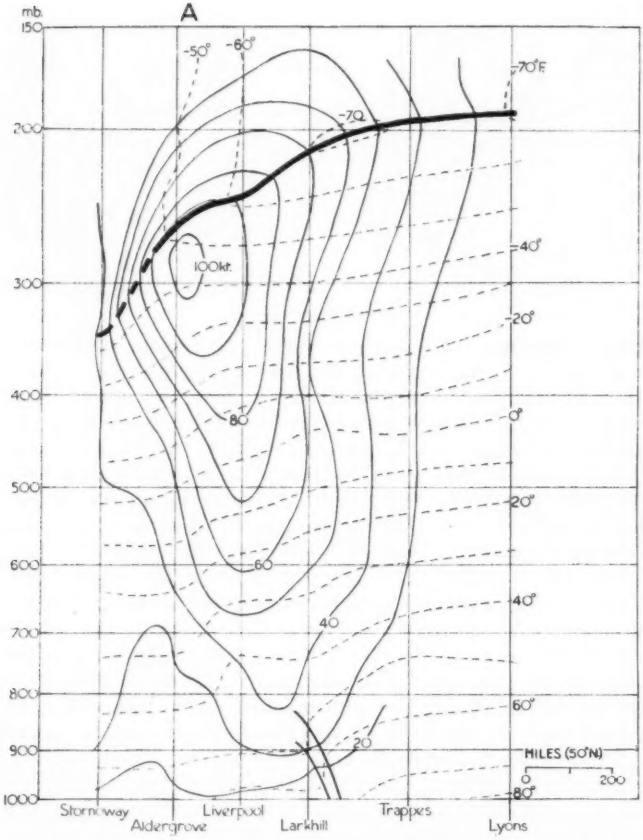


FIG. 2—CROSS-SECTION, STORNOWAY–LYONS, 1500 G.M.T., JUNE 14, 1951
Isotherms are drawn as thin broken lines; isokinetics as thin continuous lines

Additional evidence for the existence and behaviour of the two jet streams is contained in Fig. 7 which shows the time variation of the maximum wind speed on the section Aldergrove–Liverpool–Larkhill, based on reported winds at six-hourly intervals. The movement and change in intensity of wind maxima A and B are obvious on this diagram.

Thus the sequence of events appears to have been as follows. Jet stream A moved south-east into Europe, weakening rapidly during June 15 and disappearing completely early on June 16. Meanwhile jet stream B extended across the British Isles and moved slowly south-east, rapidly becoming the dominant system on June 15. The sequence is shown in Fig. 1 where the broad broken lines give the estimated positions of the jet-stream axes.

Tropospheric thermal field.—The thermal field during the entire period was typical of that associated with jet streams—the main feature being the broad baroclinic zone. Although the latter was a persistent feature, a great

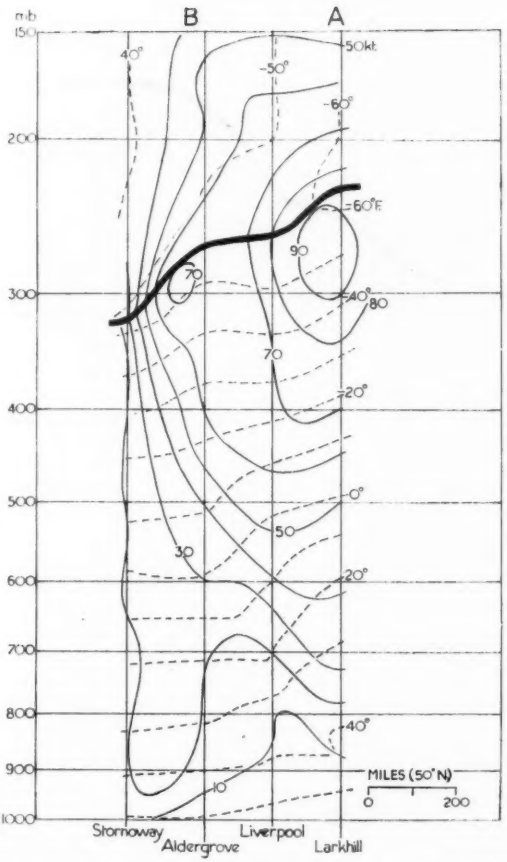


FIG. 3—CROSS-SECTION, STORNOWAY–LARKHILL, 0900 G.M.T., JUNE 15, 1951
Isotherms are drawn as thin broken lines; isokinetics as thin continuous lines

deal of complexity occurred within the zone itself. Sometimes, as in Fig. 4, several subsidiary zones could be drawn within the main baroclinic zone, although it was rarely possible to maintain the continuity of these subsidiary zones for long. Even at the same time neighbouring soundings through the broad baroclinic zone occasionally showed markedly different detailed structure; for instance, compare the soundings over Larkhill and Trappes at 1500 G.M.T., June 16 (Fig. 5). On the other hand, a narrow sloping zone is shown at 1500 G.M.T., June 18 (Fig. 6), supported also by the observations six hours earlier; however it is noteworthy that the "front" as drawn accounts for only a rather small fraction of the baroclinity that existed with the broad baroclinic zone. The transient nature of the temperature lapse-rate discontinuities within the broad baroclinic zone suggests that the analysis of the fine details (as has been done mainly for illustrative purposes in Fig. 4 for example) is of dubious value; the significant reality on the synoptic scale appears to be the broad baroclinic zone itself.

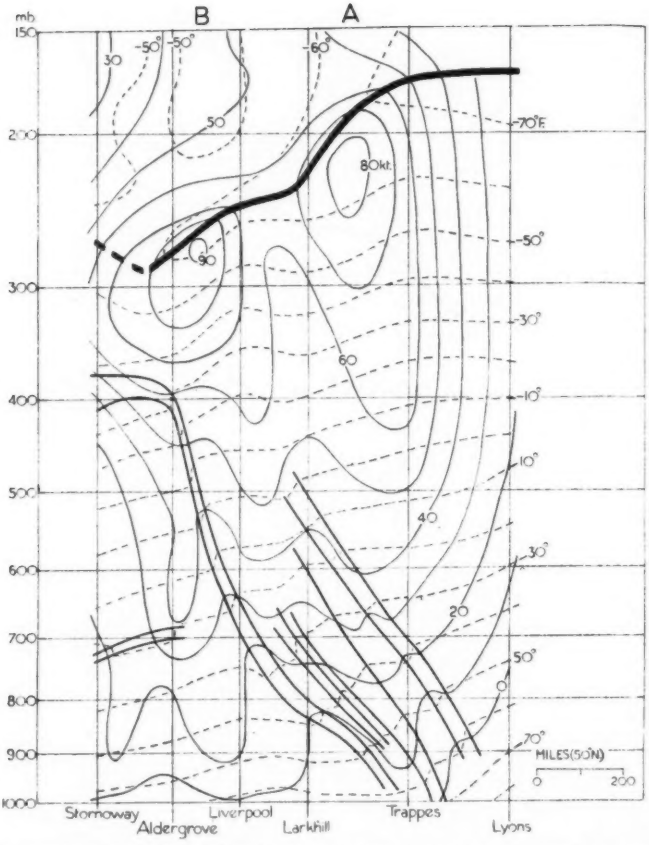


FIG. 4—CROSS-SECTION, STORNOWAY–LYONS, 1500 G.M.T., JUNE 15, 1951
Isotherms are drawn as thin broken lines; isokinetics as thin continuous lines

The behaviour of the generalized frontal zone (i.e. broad baroclinic zone) is interesting and suggestive. On June 14 it was associated both with the surface front which moved into France and with jet stream A over the British Isles. On June 15 the part of the generalized frontal zone in the lower troposphere remained closely associated with the surface front over France, but the upper tropospheric part acquired a double structure with the encroachment of jet stream B (the wavy character of the isotherms in the upper troposphere in Fig. 4 shows this feature). The rapidly weakening jet stream A and its associated baroclinic zone in the upper troposphere moved south and appeared to become detached from the almost stationary part of the baroclinic zone in the lower troposphere over France. Meanwhile as jet stream B developed and moved south its associated baroclinic zone in the upper half of the troposphere also intensified and moved south, so that soon there was re-established a broad, sloping, baroclinic zone throughout the entire troposphere. At this stage the broad baroclinic zone assumed much the same position and general shape

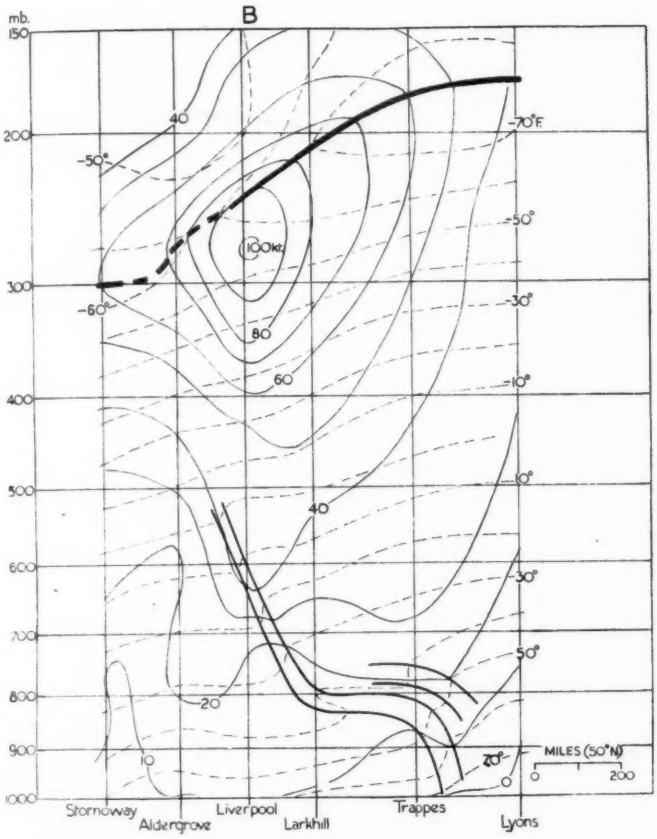


FIG. 5—CROSS-SECTION, STORNOWAY–LYONS, 1500 G.M.T., JUNE 16, 1951
Isotherms are drawn as thin broken lines; isokinetics as thin continuous lines

relative to the surface front over France as the original baroclinic zone had done. Thereafter only the single baroclinic zone and jet stream B existed. It seems as if the stable and necessary features of the forward side of the upper trough in the long-wave pattern during the period were a generalized frontal zone and associated jet stream; the complexity that occurred on June 15 quickly became damped out by these over-riding long-wave requirements.

Lateral movement of the jet streams.—The rate of lateral movement of the jet streams was estimated from the movement of the wind maxima along the Stornoway to Lyons section; for this purpose mean speeds were computed over 12-hour intervals overlapping by six hours.

The surface-pressure difference between points 200 miles on either side of the line of the section Stornoway to Lyons along the jet axes was also measured when the wind maxima A and B could be determined on the sections, and mean pressure differences over 12-hour intervals overlapping by six hours were

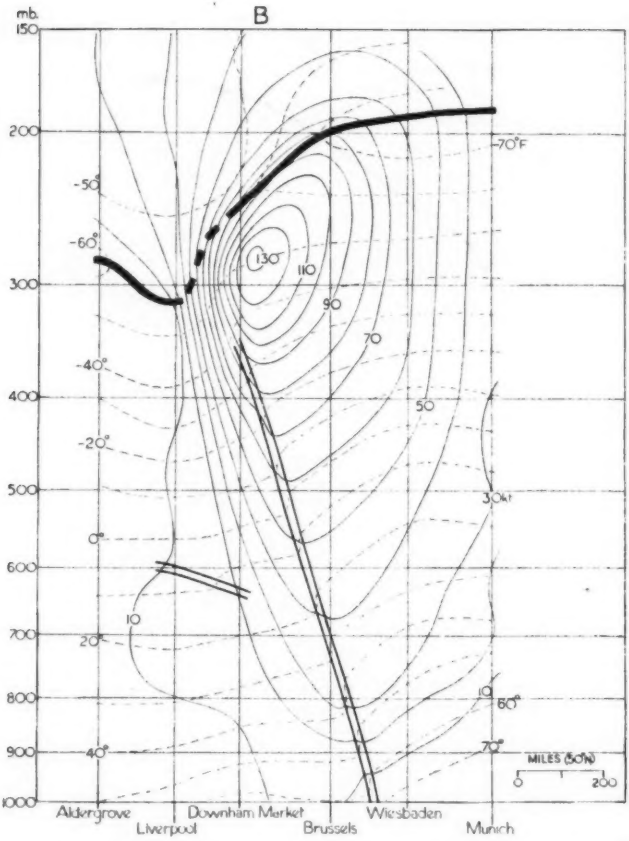


FIG. 6—CROSS-SECTION, ALDERGROVE–MUNICH, 1500 G.M.T., JUNE 18, 1951
Isotherms are drawn as thin broken lines; isokinetics as thin continuous lines

computed as a rough measure of the surface geostrophic advective component operating in a direction normal to the jet-stream axis, that is along the direction Stornoway to Lyons.

On the average the speed of lateral movement of the jet streams (A and B together) was 7·9 kt., compared with 6·5 kt. for the surface geostrophic component. The two quantities were generally in the same sense and never differed by more than 15 kt. at any time, but there was little correlation between their day-to-day variations.

There are at least two points of interest. Early on June 15 jet stream A accelerated and subsequently moved at a greater speed than indicated by geostrophic advection during the phase of rapid decay of the system. A qualitative explanation for this behaviour is that subsidence occurred to the south of the new and dominant jet stream B, thereby decreasing the baroclinity and hence the intensity of the first jet stream farther south. The movement

of the weakening jet stream A at a speed greater than suggested by geostrophic advection could then have occurred, because of an ageostrophic component from the cold to the warm air produced by descending motion in the region of vertical wind shear, as suggested by Sutcliffe[3].

The second point to note is that jet stream B moved slowly south-east at about the same speed as the geostrophic advective component and with little change of intensity for nearly two days up to the morning of June 17; thereafter it became quasi-stationary and intensified at about the same time as the geostrophic advective component increased. An ageostrophic component directed north-west against the strengthening surface geostrophic advection would be consistent both with the slowing down and the intensification of the jet stream; such an ageostrophic component might indeed be expected in the present case with the approach of the confluent jet-stream entrance.

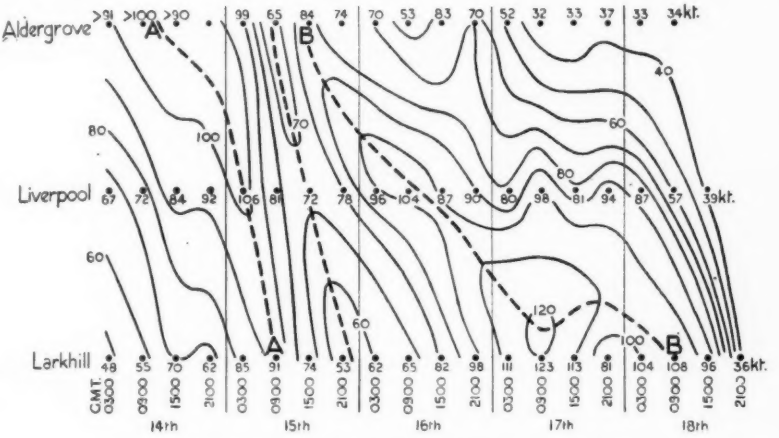


FIG. 7—VARIATION OF MAXIMUM WIND SPEED IN SECTION ALDERGROVE–LIVERPOOL–LARKHILL, JUNE 14–18, 1951

Variations in intensity of the wind maxima.—The variations in intensity of the jet streams A and B are shown in Fig. 8 (constructed from the series of cross-sections).

General subsidence to the south of jet stream B as it extended across the British Isles can be invoked to account for the weakening of jet stream A, as has been suggested in the preceding section.

The first significant intensification of jet stream B on June 17 occurred in a limited region at the base of an upper trough as it travelled north-east across England, as a non-developing wave-like perturbation on the basic jet-stream current. The trough flattened out and lost its individuality to the east of the British Isles later, although it appeared to be partly instrumental in extending the jet stream farther eastwards.

After the passage of the perturbation, the jet stream intensity in the cross-section region weakened temporarily, then increased again with the approach of the markedly confluent jet-stream entrance.

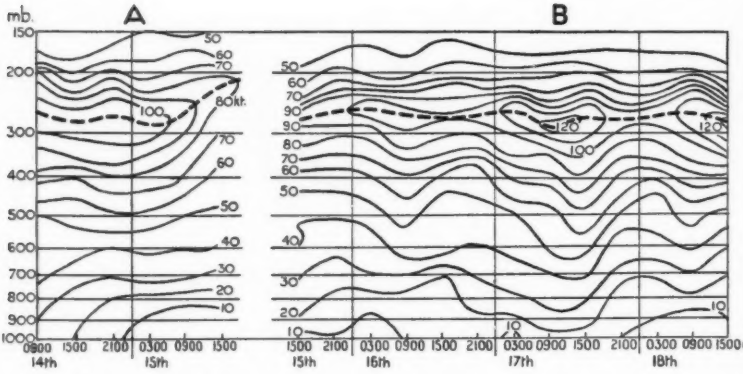


FIG. 8—VARIATION OF VERTICAL DISTRIBUTION OF WIND COMPONENTS PERPENDICULAR TO THE CROSS-SECTIONS AT THE AXES OF THE JET STREAMS A AND B

Variations in height of the wind maxima.—The variations with time of the heights of the axes of the jet streams are also shown in Fig. 8. The time scale of Fig. 8 may be regarded as a distance scale along the axes of the jet streams; the right and left of the time scale refer respectively to the entrance and exit regions of the jet streams.

First, it will be noted that the height of the axis of jet stream A changed but little until the period of decay on June 15 during which it increased rapidly. However, a section from Jever to Munich at 2100 G.M.T. on June 15 showed that the jet axis was just below 200 mb. or at about the same level as at 1500 G.M.T. on the same day over France. There is thus no definite evidence of any variation of the level of jet stream A along its length at any particular time; the higher level reported later on June 15 appears to indicate that the whole of the decadent jet stream was lifted.

Secondly, as regards jet stream B, the height remained fairly constant, the mean pressure at the jet axis during the period being 272 mb. with standard deviation about 9 mb. The probable error in estimating pressure at the jet axis is at least 5 mb., so that the apparent variability of the level of jet stream B may be unreal. Thus in this case too there is no evidence of any material change in the level of the axis of the jet stream along its length.

Tropopause structure.—Several writers[4,5] imply that the high tropopause on the high-pressure side is not continuous with the low tropopause on the low-pressure side of the jet stream. Murray and Johnson[6] have suggested that the tropopause may be continuous or discontinuous, and that the nature of the tropopause may be dependent on the life history of the jet stream.

Most of the cross-sections were readily constructed with the tropopause continuous, using an abrupt change of temperature lapse rate as the criterion to fix the tropopause and not quasi-constancy of potential temperature. Thirty-six temperature soundings on the low-pressure side at distances between 10 and 345 miles from the positions of the jet-stream axes, given on the series of cross-sections, have been examined. Of these soundings 26 gave a definite type I tropopause with an abrupt change from lapse rate to inversion; five

showed a little complexity, above the first abrupt lapse-rate change, of the type that could quite easily be explained by small-scale temperature fluctuations and instrumental errors, but no real difficulty arose in deciding the most probable position of the tropopause; the remaining five cases showed some complexity of the type that occurs with a folded tropopause[7]. One of these last five cases occurred at Aldergrove at 0900 G.M.T. on June 16 at 180 miles from the jet axis, but the complexity did not occur at Aldergrove on later ascents, nor down wind on any of the four soundings made at Leuchars on that day. The four other cases occurred at Liverpool between 0900 G.M.T., June 17 and 0300 G.M.T., June 18, at distances between 95 and 125 miles from the axis, at about the time that the jet stream had intensified to 120–130 kt. and was very slow-moving; moreover the Liverpool soundings were situated in that half of the jet stream nearer to the entrance. No soundings were available down wind at about the same distance from the jet axis. However, five soundings (Stornoway 0900 G.M.T., June 15, Aldergrove 2100 G.M.T., June 15 and 0300 G.M.T., June 16, Liverpool 2100 G.M.T., June 16 and 0300 G.M.T., June 17) were located along the line of section in the half sector near the jet-stream exit at distances varying from 70 to 120 miles; these five ascents showed simple type I tropopauses. There is thus evidence to suggest that the tropopause was continuous at one stage, at least in the exit half sector of jet stream B; but that at a later stage in the entrance half sector, when the jet stream was intensifying or had just intensified, it was folded or disrupted over a narrow zone at a distance of about 100 miles from the jet-stream axis.

A model for tropopause structure and behaviour, suggested by this case-history and other work in the literature, may be tentatively put forward. Early in the life history of the jet stream the tropopause is continuous and in some degree sloping. As the jet stream intensifies the slope of the tropopause increases, until the stage may be reached when the tropopause actually folds. The seat of the folding process is near the entrance region, as Sawyer[7] has pointed out, but the folded part of the tropopause will be advected down stream, where it will eventually be disrupted, presumably mainly by turbulence. Later, when the mechanism which produces or maintains the jet stream ceases to operate, the tropopause must become continuous again; this may come about by advection of the continuous tropopause in existence up wind or by some reformation process.

In passing, it may be of interest that the tropopause was on the average about 3,000 ft. above the jet-stream axis (the standard deviation about the mean, based on data from 14 sections, being roughly 1,000 ft.). Experience suggests that this figure is typical of jet streams of moderate intensity, say 90–130 kt.

Concluding remarks.—The most persistent feature of the five-day period appears to have been the slow-moving long-wave trough, dominating the entire troposphere, with a typical baroclinic zone on its forward side (the region analysed by the series of sections). The existence of a jet stream on the forward side of the large-scale trough is quite normal.

The distinctive feature of the period was the formation of two separate wind maxima in association with the broad generalized frontal zone. In this connexion it may be significant that the surface counterpart of the upper trough consisted for a time of a double-centred depression; the original surface

low, of which the cold front and jet stream affected the British Isles on June 14, separated into two centres about midday of June 14—one centre moved slowly into the southern Norwegian Sea where it filled up later, while the other centre developed south of Iceland, then swung south and later east towards the British Isles. Apparently the second jet stream B came into existence as a distinct entity in sympathy with the plunging south of the Icelandic low which was clearly instrumental in concentrating the thermal gradient and thus intensifying the upper current in the region south and south-east of the surface low. Nevertheless it would also have seemed reasonable if one continuous jet stream had existed, with the wind maximum being transferred temporarily northwards again early on June 15 owing to the northward advection of the main thermal belt in a limited region to the east of the surface depression. However, accepting the existence of the second and dominant jet stream B, the subsequent motion and behaviour of the first one A appears to be reasonably explicable on dynamical grounds.

Twin wind maxima within a broad tropospheric current are probably more common than was first thought, although they may be somewhat ephemeral and consequently easily missed in a wide aerological network. Certainly, during the five-day period examined, the two jet streams co-existed for little more than 12 hours.

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DIURNAL VARIATION OF RELATIVE HUMIDITY ON SEA-BREEZE DAYS IN ATHENS

By LEON. N. CARAPIPERIS

Introduction.—For some coastal areas, especially in tropical and subtropical regions, the sea breeze has a considerable influence upon the climate. This wind has some of the characteristics of a cold front. When it sets in it affects the normal variation of air temperature and humidity and irregularities appear, the magnitude of which depend on different factors such as the temperature and humidity of the displaced air, the speed of the sea breeze, the height at which the sea breeze disappears, the distance from the sea, etc. The advent of the sea breeze is accompanied by a decrease in temperature and a sudden increase in relative humidity of the coastal places[1–6], while in the places which are at some distance from the sea-shore the influence of the sea breeze upon the temperature and humidity is different and mostly unknown, because only a few cases have hitherto been examined[7–16].

This study is concerned with the influence of the sea breeze on the relative humidity in Athens on days during which the sea breeze blows without interruption.

General characteristics of the sea breeze in Athens.—The sea breeze of the Athens plain blows from SW. or SSW. with great regularity[17]. It occurs on all fine days if the general pressure gradients are weak, and it is fully developed in the warm season when the etesian winds (very persistent NW.–NE. winds blowing over the eastern Mediterranean in summer) are either absent or blowing with little speed over the open sea. Its frequency is greatest from April to October inclusive, and especially great in May, June and October [18,19]. From July to September it is often opposed by the stronger etesian winds.

The sea breeze begins at Athens 3 or 4 hr. after sunrise or earlier, reaches its greatest speed between 3 and 4 p.m., and ceases at sunset or 1–2 hr. later. The strength it attains varies according to the season. During the winter its maximum speed is about 5 m./sec. (at 2 p.m.), in spring and autumn 8 m./sec. (at 3 p.m.) and in summer 12 m./sec. (at 4 p.m.).

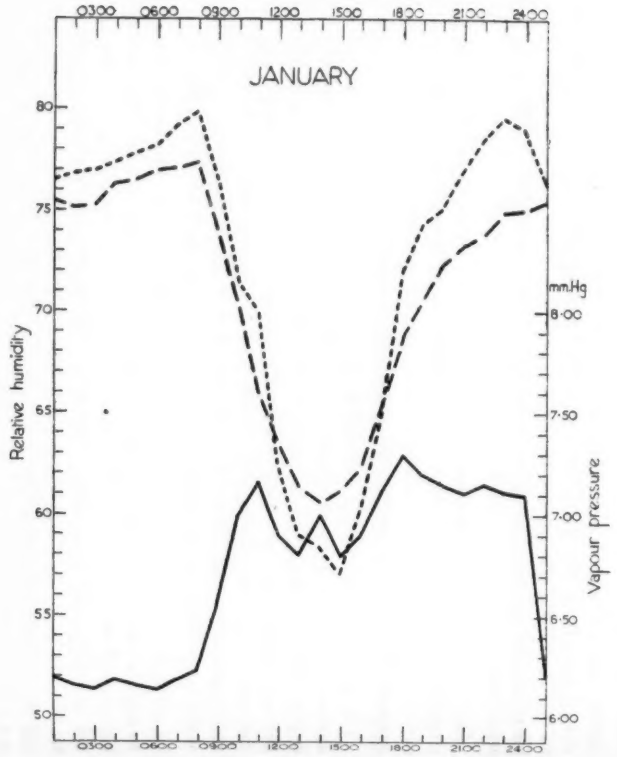
The height to which the sea breeze extends over Athens is not known exactly, but from the upper air data of the radio-sonde station at Ellinikon aerodrome it is concluded that it reaches approximately 500 m. When the etesian winds are absent and the sea breeze is strong, it is felt up to 30 Km. from the coast of Saronikos[17].

Diurnal variation of relative humidity on sea-breeze days in Athens.—In order to select days during which the sea breeze prevails in Athens without interruption, an examination was made of the records of a Dines's and a Richards's anemographs at the National Observatory, which is about 5 Km. from the sea. The total number of days having an uninterrupted sea breeze during the period 1921–30 was 550, and for these days the hourly values of the relative humidity were calculated from the records of a hair hygrograph.

Fig. 1 gives, for the months January, April, July and October, the diurnal variation of relative humidity on sea-breeze days, of relative humidity on all days (including sea-breeze days), and of vapour pressure on sea-breeze days, computed from observations made during the period 1921–30[20].

The diurnal variation of relative humidity in Athens on all days shows a maximum which occurs at 8 a.m. in January, at 6 a.m. in April and at 4 a.m. in July and October, i.e. the relative humidity shows, in Athens as in most places, a simple diurnal variation in the opposite sense to temperature. On sea-breeze days the diurnal variation of relative humidity in Athens shows mostly a double wave. If the diurnal variation of relative humidity is examined on sea-breeze days in the different months the following results are found:—

Except in the months of June, July and August, the sea breeze converts the simple fluctuation of the relative humidity into a double one. The principal minimum in the months with double fluctuation, occurs 2 or 3 hr. after noon and the principal maximum, except in December, January and February, between 10 p.m. and midnight. The secondary minimum occurs at 1 a.m. and the secondary maximum at 11 p.m. in January, at 5 a.m. in April and at 6 a.m. in October.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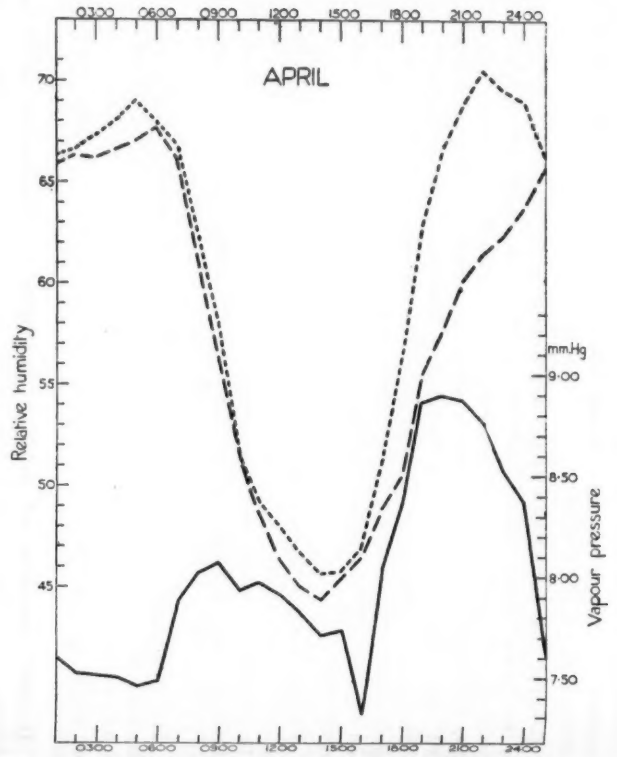
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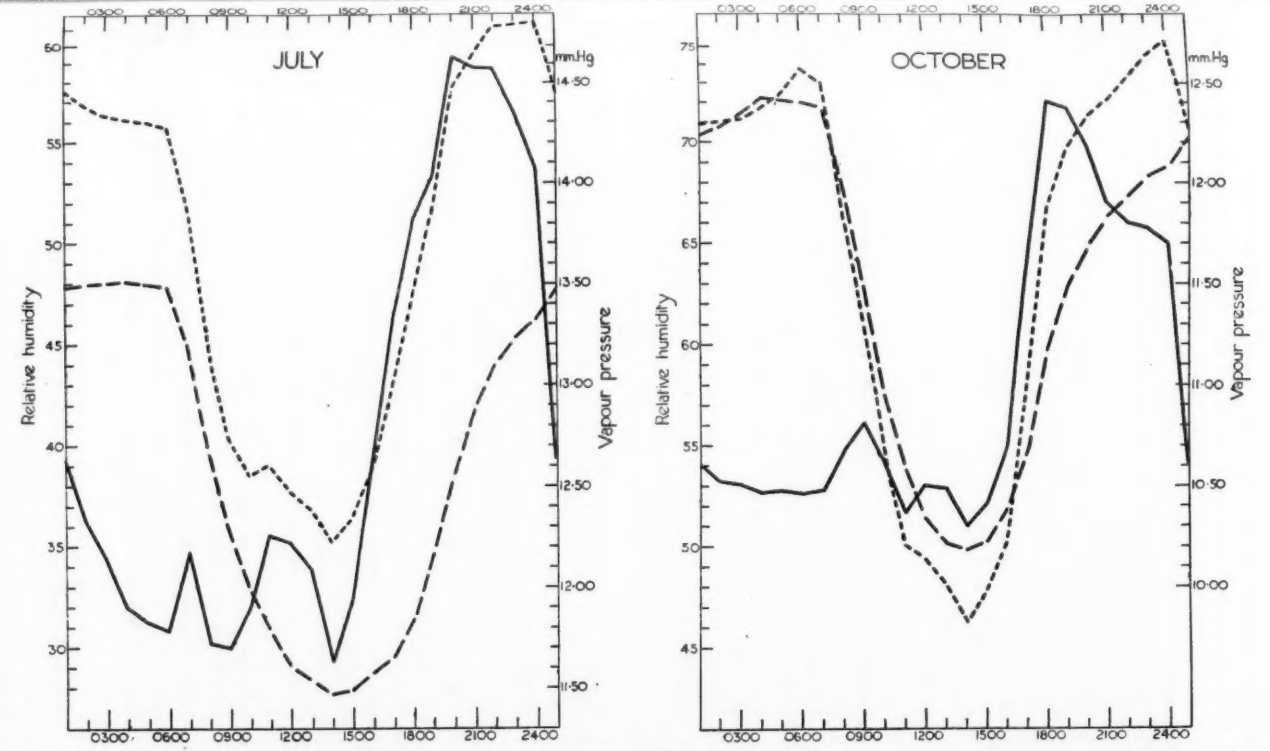

FIG. I—DIURNAL VARIATION OF RELATIVE HUMIDITY AND VAPOUR PRESSURE ASSOCIATED WITH SEA BREEZE

In all seasons and especially in summer the sea breeze considerably increases the relative humidity in the afternoon and in the late evening.

Except during the winter the principal maximum in the diurnal variation of relative humidity occurs in the evening and not at the time of minimum temperature.

The diurnal amplitude of the relative humidity on sea-breeze days is greater than it is for all days.

The arrival of the sea breeze at Athens is not accompanied by a sudden increase in relative humidity. During the months of July and August, in which the sea breeze has its greatest strength, a small increase of the relative humidity between 10 and 11 a.m. is however observed. In the other months of the warm season the sea breeze only slightly decreases the fall of relative humidity around noon.

From March to September the relative humidity throughout the sea-breeze days is greater than in the case of all days.

Explanation of irregularities and double wave.—After sunrise the air temperature increases, and though the absolute humidity is thereby increased, yet the saturation vapour pressure increases much more rapidly, so that the relative humidity decreases. The advent of the sea breeze does not stop the fall of relative humidity because of the small increase of the vapour pressure in this part of the day. During the months of July and August, when the sea breeze has the greatest strength, the increase of vapour pressure is more considerable and a small increase in relative humidity occurs at the time of the arrival of the sea breeze. Thus the relative humidity from the maximum of the early morning decreases steadily until between 2 p.m. and 4 p.m., when the minimum of vapour pressure and the maximum of air temperature occur. Afterwards the relative humidity begins to increase rapidly at a much greater rate than in the days without sea breeze, because of the fall of temperature and especially because of the great increase of vapour pressure. This increase, which appears in the afternoon of sea-breeze days, is due on the one hand to the decrease of vertical convection currents and on the other hand to the fact that the sea breeze continues to carry over the Athens area large quantities of moisture until sunset and even a little later. The increase of the relative humidity continues until the late evening and the principal maximum in its diurnal variation appears between 11 p.m. and midnight. After that time because the vapour pressure falls much more rapidly than the saturation vapour pressure, the relative humidity decreases. About one hour later, because the temperature decreases steadily and the vapour pressure ceases to fall, the relative humidity increases. Thus the second minimum of relative humidity appears, after which it begins to increase until about the time of the minimum of temperature.

In summer, and especially in July and August, the second maximum and minimum of the diurnal variation of relative humidity disappear, because the vapour pressure from the principal maximum of the late evening falls steadily during the night until the minimum of the morning, and the temperature on summer nights falls little. In addition, this continuous fall of relative and absolute humidity is due to the fact that in summer after the sea breeze either the etesian wind or the land breeze blows[18], and these winds carry drier air masses over the Athens area than the sea breeze.

[To face p. 144

By courtesy of the Daily Mail

MOCK SUN, PETT'S WOOD, KENT, 1500 G.M.T. FEBRUARY 25, 1953

By courtesy of K. E. Woodley

RIME ON *Distylium Racemosum*, KEW, 1330 G.M.T., DECEMBER 7, 1952
(see p. 158)

By courtesy of K. E. Woodley

RIME ON *Pinus Wallichiana*, KEW, 1350 G.M.T., DECEMBER 7, 1952
(see p. 158)

To face p. 145

By courtesy of R. K. Pilsbury

THICK FOG, NORTH HARROW, 1800 G.M.T. DECEMBER 7, 1952
(see p. 158)

The great increase of relative humidity in the afternoon on sea-breeze days is also demonstrated from the upper air data of the radio-sonde station at Ellinikon. Fig. 2 shows the variation with height of the relative humidity computed from observations made at 5 p.m. in July and August of the years 1947, 1948 and 1950. From this diagram it is clearly concluded that the relative humidity on sea-breeze days is much greater, especially in the lower layers of the atmosphere, than on etesian days up to a height of about 600 m.

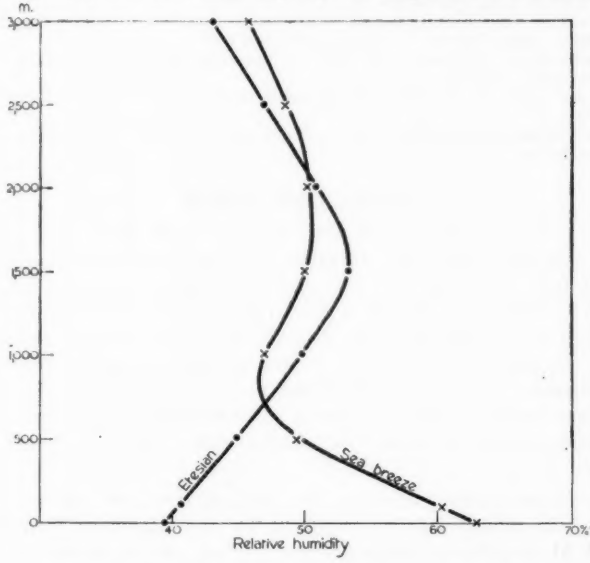

FIG. 2—VARIATION OF RELATIVE HUMIDITY WITH HEIGHT
Time of observation: 1700 Period: July, August, 1947–48, 1950

Eginitis[21] mentioned that in the diurnal variation of relative humidity in Athens there sometimes appears a double wave which was not however attributed to the sea breeze by the author. Also the explanation which was given by Angot[22] is not complete.

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"SELECTED" SHIPS

By Cmdr C. E. N. FRANKCOM, R.N.R. (Retd)

It is common knowledge that in order to obtain adequate meteorological information from the oceans the assistance of voluntary observers aboard merchant ships has to be obtained. It is true to say that practically all the meteorological information that has been obtained from the oceans during the last 100 years has been thus provided by these seagoing amateur meteorologists. This information has been supplemented by that provided by Naval vessels, from the occasional voyages by special research ships, and, of recent years, by the ocean weather stations which have been established in the Atlantic and Pacific.

The arrangements for obtaining observations over the oceans under the "selected" ship scheme are co-ordinated by the Maritime Commission of the World Meteorological Organization. There are at present some 2,300 "selected" ships in the world, of which 500 are British. All these ships make observations, as far as the exigencies of the officers' duties permit, at the main synoptic hours (0000, 0600, 1200 and 1800) and they are, in principle, supplied with tested instruments. Every effort is made by the Marine Branch of the Meteorological Office constantly to improve, as far as possible, the network of observations over the oceans. That these efforts are successful can be shown from some figures concerning the network in the eastern part of the North Atlantic. In 1939 there was a total of 360 British "selected" ships, and in the eastern Atlantic (north of 35°N. and east of 40°W.) a total average of 52 reports a day was received at Dunstable from British and foreign "selected" ships. A map showing the distribution of "selected" ships on March 4, 1953, is given as Fig. 1. During the war it was impracticable, for military reasons, for merchant ships to keep meteorological log-books or to transmit radio weather messages. British "selected" ships resumed making their observations on November 1, 1945, and by the end of that year the average number of reports received in the eastern North Atlantic was 20.

Figures for the years 1946 to 1952 are as follows:—

1946	...	54	1950	...	90
1947	...	80	1951	...	105
1948	...	81	1952	...	118
1949	...	82			

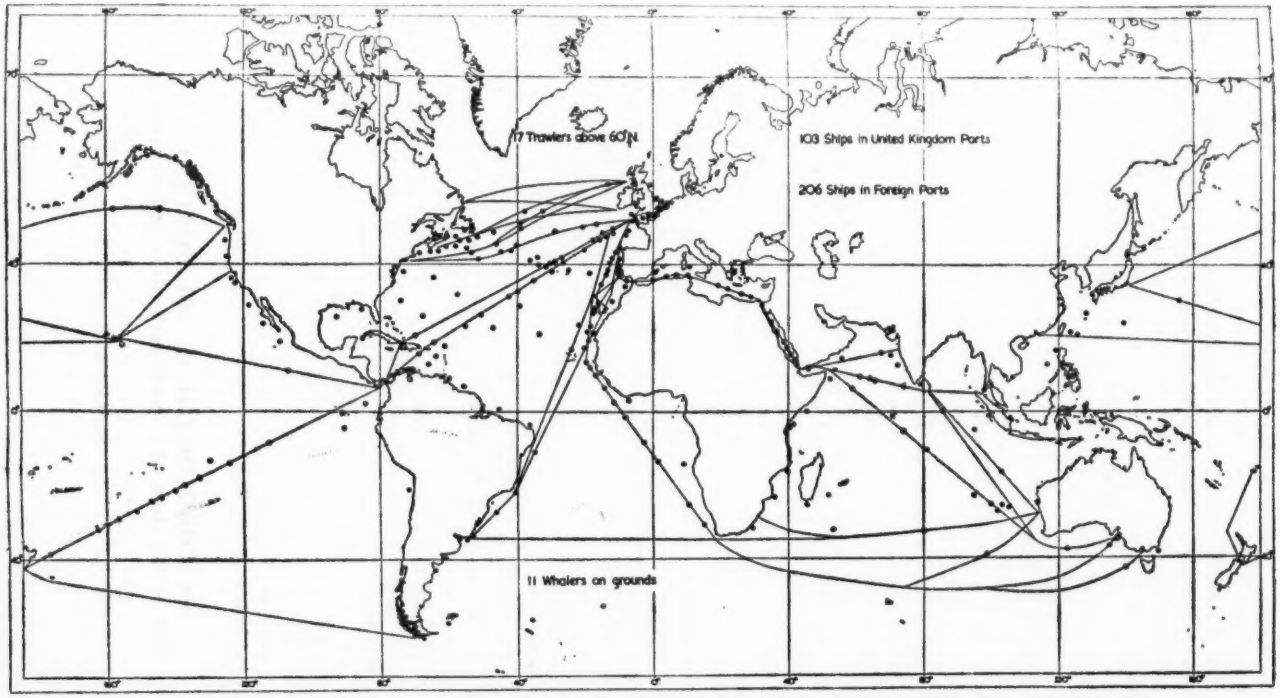

FIG. 1—THE POSITIONS OF BRITISH SHIPS WHICH MADE METEOROLOGICAL OBSERVATIONS ON MARCH 4, 1953
A day picked at random

Thus there has been a gradual increase in the number of reports received throughout the years. It seems from these figures that the meteorological network at sea in the eastern Atlantic is relatively good, but one has to remember that these total reports on a given day represent approximately only a quarter of the number of ships, and all those ships are moving, and the ships themselves tend to be concentrated on the main shipping tracks. There are therefore, inevitably, considerable gaps in the network, but in the eastern North Atlantic it is fortunate that these gaps are, to some extent, closed by the presence of the ocean weather ships.

A similar picture prevails in the western North Atlantic, where it seems that the network is at times, and in some parts, even denser than in the eastern portion of that ocean. Here again the gaps are, to some extent, filled by the presence of weather ships.

In the other oceans of the world the picture is by no means so good, but the World Meteorological Organization is doing its best to encourage those countries which operate "selected" ships to concentrate on recruiting for this work vessels which trade to the more unfrequented parts of the world. A particular example of this is in the Southern Ocean, where success has attended the recruiting of whaling ships, for which a special "position cypher" has been arranged so that they do not have to disclose their position to rival whaling ships when they send their weather messages by radio. This season 11 British whaling ships have been recruited.

From a study of the meteorological log-books sent in by British "selected" ships the quality of the observations is high. The observers in these ships are encouraged by every possible means to make their observations accurately, but there are, nevertheless, certain difficulties inherent in ships' observations which are, to some extent, unavoidable, so that inaccuracies are bound to occur from time to time. This particularly applies to air and sea temperature and humidity.

The radio officers of the ships play an important part in this work, but one difficulty is that many of the ships only carry one radio operator, and the messages have to be transmitted when he is on watch. Statistics show that during the year 1952 about 77 per cent. of the messages to Dunstable were received within two hours of making the observation and about 57 per cent. within one hour.

It is of interest that 93 of the present "selected" ships were carrying out duties as "selected" ships before 1939. These figures perhaps emphasize the enormous shipping casualties which the United Kingdom suffered during the last war, because the general tendency is for any ship to remain a "selected" ship once it has been recruited.

METEOROLOGICAL OFFICE DISCUSSION

The application of wave-length ideas in forecasting

The discussion on Monday, February 16, 1953, held at the Royal Society of Arts, was opened by Mr. E. J. Sumner who based his statement on tests made and forecasting experience gained in the Forecasting Research Branches, Dunstable.

He said that wave-length concepts derive from the Rossby wave-speed formula, which is applicable to the long waves of the atmosphere. These are

amongst the most persistent and frequently recurring features of upper flow patterns, and are therefore especially important in extended forecasting. Although there is no exact and invariable correspondence between upper and lower patterns, as a rule they are sufficiently interdependent to make the forecasting of the former of some importance in preparing surface prebaratics. This is especially so in respect of the larger scales of motion; in particular, long waves have thermal and contour patterns which are more or less in phase at all heights. Thus the wave form, which is clearly delineated at the 500-mb. level, becomes stronger with height up to the tropopause; thereafter, with the usual temperature-gradient reversal in the stratosphere, the long-wave pattern fades with increasing height.

An example of a well defined long-wave train encircling the northern hemisphere (500-mb. contour, surface and 1000–500-mb. thickness charts for 0300 G.M.T. on December 12, 1950) was shown illustrating the above characteristics. Other characteristic features remarked on were the strong flow in the centre of the "waving stream" (the meandering jet) with relatively slack areas to north and south, and the presence of smaller waves superimposed on the long-wave pattern. The importance of distinguishing between short and long waves was emphasized, since the formula in question refers only to the latter.

The shorter waves may be divided into two broad classes, namely, short stable waves and short unstable waves. The former may take the form of the merest ripple on 500-mb. charts, the thermal and contour patterns in the lower layers being in anti-phase. They are usually very mobile, the associated surface systems being steered by the upper flow and may deepen or intensify to a moderate extent. The latter have phase differences between the thermal and contour patterns, intermediate between long and stable short waves. These unstable features too tend to be steered by the upper current, at least in the early stages of growth. Mr. Sumner said that the above indications were very rough; it was not always possible to distinguish between stable and unstable waves by simple inspection of contour and thermal patterns, nor was it always possible to segregate waves according to scale, especially when the smaller were growing rapidly. At such times they were liable to disrupt pre-existing long waves, although this was not invariable; they may merely "phase in" with or accommodate themselves to the established régime, temporarily distorting the long-wave profile. The occurrence of these instabilities coincides therefore with a rather critical period in forecasting.

Rossby[1] adopted a simple sinusoidal model of the long waves, and, assuming a barotropic, inviscid atmosphere, arrived at the following formula:—

$$c = U - \frac{\beta L^2}{4\pi^2} \qquad \ldots\ (1),$$

where c is the wave speed (positive, eastwards; negative, westwards), U the mean zonal wind, L the wave-length and β the rate of change of Coriolis parameter with latitude. The basic theory has been re-interpreted in recent years by Charney[2], and its practical application to the earth's atmosphere (which in middle latitudes is almost always and everywhere baroclinic) justified in an "equivalent-barotropic" sense. This implies, to a first approximation, the conservation of the mean vorticity of a vertical column of the atmosphere (from top to bottom), and the Rossby formula should be applicable

to the mean flow of the baroclinic atmosphere, the mean flow pattern being identified for practical purposes with the 500-mb. chart. Other formulae have been derived for more complex, and in some respects more realistic, models of long waves, but all of them include the two main terms of the Rossby form, modified by other parameters or averaged in some way. It is evident therefore that some empirical modification of the simple formula given in equation (1) is required in practice.

The results of a test of the formula as applied to the movement of pairs of upper troughs at the 500-mb. level[3] showed reasonably encouraging results—correlations between the actual and estimated 24-hr. movement of down-wind troughs of over 0·9 were obtained for the cool seasons of the year when various errors were smoothed out by 3-day averaging. Nevertheless it was not found possible to improve on the forecasts made at the Central Forecasting Office, Dunstable (which then (1950) owed nothing to the Rossby formula) of the 24-hr. movement of upper troughs. Although it seemed probable that the technique could be refined so as to equal or even to improve on present forecasting standards, it was considered best to develop some simple practical technique based on the formula, which the forecaster could absorb into his routine, gaining experience on its use under actual working conditions.

The most convenient form for forecasting is

$$c = \frac{\beta}{4\pi^2}\,(L_s^2 - L^2) \qquad \ldots\ (2),$$

where $L_s = 2\pi\sqrt{(U/\beta)}$ is the stationary wave-length (derived from equation (2) by putting $c = 0$). Although empirical adjustments are required in general, experience has shown that the use of a zonal parameter U_2 would give a reasonably good estimate of the wave speed of the down-wind trough of a pair without much modification of the above expression. U_2 is computed at the 500-mb. level for a latitude band 20° wide, just containing a pair of troughs and more or less central to the wave train. (The "minimum pattern" on which measurements can be made consists of two troughs with an intervening ridge.) On comparison with the actual wave-length of quasi-stationary troughs it was found that the computed stationary wave-length over-estimated the true value by about 8° longitude on an average (one year's data). This tentative value should therefore be subtracted from all determinations of the stationary wave-length based on U_2. The measurement of the other parameters[3] was also described, and a method of evaluating the above formula by graphical means presented, the entire procedure taking only 3–4 min.

A slide was shown illustrating the "success" of the formula under simulated forecasting conditions. The more progressive waves moved well in accordance with the formula, but those forecast to be slow-moving or retrogressive still showed a decided tendency to progression. In some cases this was merely a question of shorter-waves interfering with the measurements (made in accordance with a rigid procedure), the long wave being actually quasi-stationary or retrogressive as forecast, but there were some cases of definite failure.

The remainder of the opening statement was devoted to illustrating and describing types of synoptic situations to which wave-length ideas were or were not expected to be applicable. Although the final choice rests with the experienced forecaster, the following simple rules may be put forward as a guide to selecting the best situation in which to apply the formula:

(i) The 500-mb. pattern should consist of at least a pair of troughs and an intervening ridge, with a fairly definite, broad, single, connecting flow between the two. It should be reasonably sinusoidal in form.

(ii) Clearly defined long waves of any amplitude may be tackled, bearing in mind, however, that the smaller amplitude waves tend not to be conserved, and, at the other extreme, that very large amplitude waves are likely to be non-sinusoidal or to be disrupting in some manner.

(iii) The presence of short waves should be smoothed out as far as possible when making measurements and interpreting the results.

(iv) The wave profile should not be changing its form or amplitude too rapidly at the time of forecast.

Straightforward cases of progressive, stationary and retrogressive long waves were shown. One case of forecast progression (April 14–15, 1952) was especially interesting in that the surface low on the western Atlantic associated with the upper trough was almost concentric with a cold pool; it was not therefore evident from thermal steering that a substantial movement eastwards should have occurred, as it did.

Retrogression is almost invariably a discontinuous process in which, for example, the original long-wave trough moves away eastwards declining, while a deepening trough moving round the ridge immediately up wind intensifies and "takes over", settling down further west than its predecessor. This pattern of change may be equally well described as a short unstable wave being steered round the larger-scale trough, which is simultaneously moving westwards.

The formula may also be applied to more complicated patterns, for example to double-wave trains in different latitude bands (two-storey structures). These trains may move independently for a time, but the phasing in of troughs and/or ridges of the adjacent trains is always a possibility (see, for example, the situation in the Atlantic sector on November 18–20, 1952). This eventuality is usually associated with radical and rapid over-all changes of the pattern, which for a time may make computations useless. Another complex type is that of a "block", which in a sense is a persistent two-storey anti-phase wave pattern. Wave-length concepts may be applied to give indications of the movement, east or west, of the block itself. The sustained blocking retrogression of May 5–19, 1950, was illustrated.

Finally, examples of the cutting off of a cyclonic vortex at the "tip" of a trough, the rapid formation of a long wave from a short unstable wave (April 19–23, 1950), and the equally rapid break-down of a long-wave pattern by smaller-scale instabilities (December 17–18, 1950) were shown. In some cases wave-length ideas were definitely suggestive of future developments (e.g. cutting off by differential movement in different latitudes), but during such times of rapid change quantitative estimates were often of dubious value; rapidly growing waves often move very much more slowly than the formula indicates.

In conclusion, Mr. Sumner said that one was always tempted to apply the formula to patterns which were very unlike the Rossby model—to force the atmosphere into a sinusoidal mould—which must lead to errors. Some of these would undoubtedly be anticipated if the full implications of the conservation of vorticity were to be worked out from the actual initial flow pattern, which was now possible with the aid of electronic computing machines. These methods,

although likely to supersede such techniques as the above, were still, however, in the experimental stage. Meanwhile wave-length considerations could serve as a simple introduction to modern dynamical ideas; and, incidentally, the value of looking at the large-scale developments on upper air charts in their own right was not negligible.

The Director, opening the discussion, remarked on the contrast between the complexity of actual atmospheric flow and the simplicity of the Rossby model. He thought that the formula would frequently break down owing to new developments. He also noted that whereas the correlation, between actual and estimated 24-hr. movement of troughs in the data shown, was good in progressive cases, it seemed to decrease to practically zero in cases of retrogression. Mr. Sumner, in reply, agreed that developments in the patterns were always likely to occur resulting in errors. The small correlation in cases of retrogression was, in part at least, due to the complex nature of the process (interference by smaller scales of motion) and improved considerably with smoothing.

Mr. Bushby said that one of Rossby's main assumptions was that of the conservation of absolute vorticity. Charney[2,4] had adapted this concept to enable him to predict changes in the 500-mb. contour height, and his methods had been tested at Dunstable. An earlier method was essentially one-dimensional, and assumed that the 500-mb. flow consisted of small sinusoidal perturbations superimposed on a west–east zonal current, constant with respect to time and longitude. However, tests showed this method to be inferior to conventional methods in forecasting changes of contour height, but that it was as good in forecasting the 24-hr. movement of troughs and ridges. Two examples were shown. The second method, utilizing the geostrophic approximation in the vorticity equation, gave instantaneous 500-mb. height tendencies. A modification of Charney's equation by Sawyer and Bushby[5] allowed some account to be taken of baroclinic development, but tests had shown that, although the baroclinic terms were significant, the main effect was often represented by the barotropic term. Only a few situations had so far been examined, but in each case when a grid length of about 160 miles had been used there was reasonable agreement between the computed and actual 500-mb. height tendencies. One example was shown. In his opinion, when the flow was sinusoidal the Rossby formula should give a useful approximation to the movement of troughs and ridges.

Mr. C. V. Smith spoke about down-stream effects. The usefulness of a qualitative assessment of constant-vorticity trajectories was illustrated; such a technique could be employed even when flow patterns did not approximate to the simple sinusoidal model required for a confident application of the Rossby formula, and could be more informative about changes of trough amplitude or orientation of axes. One suggestion that arose from the barotropic approach was that the formation of a major trough in the upper westerlies should give rise to a dependent wave train down stream. Examples of down-stream trough formation were shown (October 28–31, 1949; February 9–15, 1950) in which it seemed that the evolution (e.g. the spacing and amplitude finally achieved) of the flow patterns, initiated by baroclinic developments, was in some large degree determined by inertia processes. Some results were quoted[6]. These suggested that the persistence of a major trough in the upper westerlies for 2–3 days, led to the next down-stream trough having dimensions

comparable with that of the up-wind trough. The possible importance of so-called "anchor troughs" for long-range forecasting was also alluded to.

Dr. Forsdyke described the results of the application of long-wave considerations to extended forecasting in the Central Forecasting Office, Dunstable, over the period December 1952 to January 1953. The wave-length computation, regarded simply as indicating progression, slow movement or retrogression of the long-wave pattern, gave the right answer on about 60 per cent. of occasions. The great majority of these were cases of progression which would probably have been forecast in any event. Nevertheless he believed that wave-length considerations often gave useful indications of the broad type of evolution over a 3- or 4-day period. A recent example was discussed showing how the breaking down of a ridge of high pressure across the British Isles from Scandinavia by a small depression moving south-south-east from Iceland was successfully forecast (on broad lines, though not in detail) on the basis of the wave-length computation.

Mr. Murray asked how the use of the Rossby formula compared with extrapolation. Mr. Sumner replied that according to some results of Cressman[7], there was a slight gain in using the formula. However, if waves had only recently formed extrapolation could not be used whereas the formula could. Moreover, the forecaster sometimes had little confidence in continuing a trend because owing to observational uncertainties he was not convinced it was real, e.g. a recent rapid deceleration; wave-length ideas could provide confirmation or otherwise.

Mr. Bannon asked how retrogression, which seemed to be effected by the formation of baroclinic disturbances, could be anticipated on the basis of a barotropic model. Mr. Sumner, in reply, said that the application of such models to the baroclinic atmosphere had subsequently been justified in a mean or "equivalent barotropic" sense. The "eddy" terms, which entered into the vorticity equation after meaning vertically throughout the atmosphere, were probably biggest in association with smaller-scale baroclinic disturbances, but with respect to changes at the 500-mb. level even these seem to be dominated by the (inertia) control associated with the mean terms.

Dr. Stewart, referring to some of the results given by Dr. Forsdyke, said that better results would have been obtained if all troughs had been forecast to be progressive. Dr. Forsdyke agreed that this was statistically true, but that against this the formula gave an indication of the speed.

Dr. Scorer and *Mr. Bushby* then discussed the merits of Fjørtoft's graphical method for integrating the vorticity equation.

Mr. Lumb emphasized the importance of land–sea contrasts in modifying long-wave patterns.

Dr. Stagg said that he was still uncertain about the Rossby formula, and considered that the barotropic approach put the 500-mb. flow pattern in a false position as something apart from the rest of the atmosphere. Also, in his opinion, retrogression was best thought of as a process of cutting-off and trough reformation.

Dr. Sutcliffe spoke on the lead that Professor Rossby had given and the unanimity which at present prevailed in research on numerical methods. It would take some time before any great confidence could be entertained in their use; meanwhile forecasters should begin to apply dynamical concepts, if only qualitatively.

Mr. Gold noted that the formula had only been applied to the motion of a single trough, when there were others in the picture. He also stressed the importance of the effect of mountain ranges on upper-flow patterns, and asked if the theory fitted better in the southern hemisphere where there was little interference from land masses. Mr. Sumner, in reply, said that the motion of each trough which had an up-wind counterpart could and should be considered; for periods up to 24 hr. the motion of a trough was largely determined by the initial characteristics of the patterns, but for longer periods what was happening to the up-wind member also had to be considered. He had no experience of southern-hemisphere patterns, but agreed that the effect of topography was very important, possibly more so than the land-sea contrast.

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METEOROLOGICAL RESEARCH COMMITTEE

At the meeting on January 22nd the Synoptic and Dynamical Sub-Committee considered two papers on upper winds, one by Mr. D. G. Harley[1] giving an analysis of the equivalent headwinds on the great circle Shannon–Gander, and a second by Mr. C. S. Durst[2] showing the relation between the wind flow over the British Isles and the Mediterranean. Two papers of synoptic interest were also discussed, one by Messrs. C. V. Smith and A. G. Forsdyke[3] on some down-stream features associated with large amplitude troughs in upper air circulation patterns, and a second by Mr. D. H. Johnson[4] on the wind field of middle latitudes. A paper by Mr. Hurst[5] on the profile of a jet stream which was observed on September 1, 1952, aroused considerable interest. The relative merits of isotachs and contours for forecasting winds at high levels were also discussed.

ABSTRACTS

1. HARLEY, D. G.; Analysis of equivalent headwinds on the great circle Shannon–Gander, and of errors in forecasts of the same, at London Airport. *Met. Res. Pap., London*, No. 749 S.C. II/117, 1952.

Equivalent headwinds are measured from forecast 700- and 500-mb. contours; the procedure and sources of error are discussed. The monthly distributions and extremes of actual equivalent headwinds and percentage frequency distribution of errors, are tabulated and discussed. The mean errors were very small, but standard deviations ranged from 6·5–12·7 kt. Large errors were mainly due to timing of developments.

2. DURST, C. S.; The relation between wind flow over the British Isles and the Mediterranean. *Met. Res. Pap., London*, No. 776, S.C. II/133, 1952.

Winds at 200 mb. over Larkhill were correlated with those over Rome and Malta. Vector coefficients (−0·15 to −0·30) were significant at all seasons, possibly indicating a partial compensation in zonal flow.

3. SMITH, C. V. and FORSDYKE, A. G.; Some down-stream features associated with large amplitude troughs in upper air circulation patterns. *Met. Res. Pap., London*, No. 752, S.C. II/118, 1952.

Circumpolar 500-mb. polar charts were examined for simple troughs over America on 4 following days. Changes in amplitude or new formations of down-stream troughs are tabulated,

but little relation was found except when the "primary" trough persists for 2–3 days. The same procedure was applied to 1000–500-mb. thickness troughs. The results do not suggest that oscillations are regularly transferred down stream, but rather the development of each trough by local energy. The modes of formation of down-stream troughs are classified as (*a*) simple growth, (*b*) amalgamation or "phasing in", (*c*) blocking patterns. Examples illustrated are: (*a*) Feb. 13–15; (*b*) Apr. 21–23; (*c*) Jan. 24–28, May 17–19, Nov. 25–27.

4. JOHNSON, D. H.; Further notes on the wind field of middle latitudes. *Met. Res. Pap., London,* No. 761, S.C. II/123, 1952.

Structure of upper westerlies in January 1950 is studied by daily cross-sections (1000–150 mb.) from Greenland to Mediterranean and Azores to Baltic, with contours of 1000- and 300-mb. surfaces over the whole area. All showed a central maximum of jet-stream type near the tropopause. The summary for the month includes histograms of height (peak 300–325 mb.), mean velocity profiles and shear profile referred to centre of jet, mean cross-section Angmagsalik–Tunis, etc.

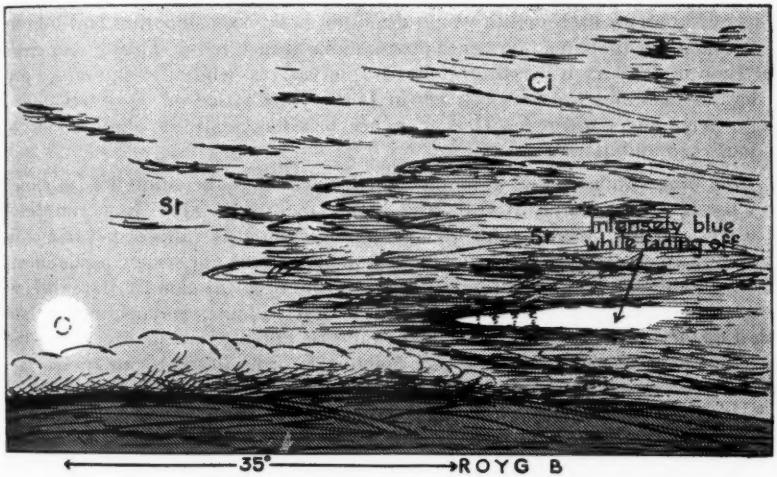
5. HURST, G. W.; The profile of a jet stream observed September 1, 1952. *Met. Res. Pap. London,* No. 772, S.C. II/131, 1952.

Wind profile of a flight from Bedford to north Scotland at 300 mb. on September 1, 1952, is discussed. Between 55° and 56°N. jet stream (110 kt.) blowing from 245° was crossed. For comparison a vertical section is constructed from radio-sonde ascents.

LETTER TO THE EDITOR

Rare mock sun seen from Gresford, Denbighshire

I first noticed a very brilliant patch of light at 1510 on December 12, 1952, and was immediately impressed by its brilliance and colouring, the latter being most vivid and noticeable. The patch appeared, as indicated in the sketch, rather like a comet with a brilliant tail. The "nose" ranged rainbow fashion from deep red to green then followed an intensely blue-white tail which faded off into the background of cloud.



I took a sight on the distance of the nose from the sun, using the only means at my disposal, a protractor and two pins. The mean angle I obtained from four sights was 35° with a variation of $\pm 1\frac{1}{2}°$. The patch of light was in line with the sun horizontally, and appeared to be in a large cirrus sheet behind a lot of stratus which subsequently blotted out the phenomenon.

R. SCUTT

85 Box Lane, Wrexham, North Wales, January 19, 1953

[This phenomenon appears to have been the mock sun associated with the

rare halo of 32° produced by refraction through pyramidal ice crystals as described by Humphreys*.—Ed., *M.M.*]

NOTES AND NEWS

Frequency of cloud at mountain summits

In a note on the radio-telephone station at Great Dun Fell, Cumberland, in this Magazine for October 1951, it was stated that this station at the summit, 2,780 ft. above sea level, is almost permanently in cloud in winter. A more precise statement can now be given as a result of observations made by the radio-mechanics on duty there. They recorded whether the station was in or out of cloud, initially at 0900, 1500 and 1800, and later at 0900, 1200, 1500, 1800, 2100 and 2400. There was a break in the records but the observations cover three Januaries, three Februaries and two each of the other months within the period December 1948 to June 1952. The results are summarized in Table I.

TABLE I—FREQUENCY OF REPORTS OF STATION IN CLOUD AT GREAT DUN FELL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	percentage frequency												
0900	55	59	53	52	24	41	34	55	45	48	63	55	49
1200	71	59	65	43	16	32	24	35	50	30	59	...	45
1500	53	51	61	33	16	15	23	19	33	33	63	53	37
1800	58	51	54	33	27	19	20	27	32	37	65	58	40
2100	74	69	62	47	47	30	24	47	73	59	82	...	57
2400	68	69	62	47	50	52	36	63	71	64	89	...	62

The values for each month would doubtless have been smoother had it been possible to use the same number of observations at each hour. Thus 71 per cent. at 1200 in January is based on only 62 observations, while the 55 and 53 per cent. at 0900 and 1500 respectively in January are based on 93 observations. The percentages given for December are based on only 38 observations at 0900, 1500 and at 1800.

The observations show, as would be expected, that the summit is in cloud on the fewest occasions at 1500 and in the months of May, June and July. Clearly also the observers did not regard the station as "almost permanently in cloud in winter". The writer of this article could not secure a statement from the observers of the criterion used for entering "in cloud", but working under such conditions they may well have adopted a high standard, higher than that of the normal office worker who would be appalled at the severity of the weather experienced in winter at such heights. In order to add to our knowledge, the observers are being asked to record, in future, additional information as to the furthest observation post which can be seen, the posts being set up at distances of 10, 22, 44 and 110 yd.

During the period when observations were made six times a day, the station was in cloud continuously at these times for over seven days from 0900 on January 4 until 1800 on January 11, 1952. The longest period when the station was out of cloud was four days, in May 1952.

Similar observations were made at the radio station on Lowther Hill, 2,377 ft., near Wanlockhead, to the north of Dumfries, but they were restricted to 0900, 1200, 1500 and 1800. The percentage frequencies of station in cloud

* HUMPHREYS, W. J.; Physics of the air. 3rd edn, London and New York, 1940, p. 534.

are set out in Table II. The observations at Lowther Hill given for December are based on only 38 observations, at 0900, 1200, 1500, and 1800, by far the fewest for any month. Too much weight should not be given therefore to the smaller percentages in December than in January and November.

TABLE II—FREQUENCY OF REPORTS OF STATION IN CLOUD AT LOWTHER HILL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	percentage frequency												
0900	60	60	47	55	32	34	31	56	37	65	63	43	48
1200	59	52	41	46	26	23	20	43	40	40	59	46	40
1500	64	52	38	40	35	21	20	34	30	50	55	43	39
1800	62	54	40	52	39	22	22	37	48	59	69	55	44

It is interesting to note that, taking all the values, the percentages at 0900, 1200, 1500 and 1800 are very similar at Great Dun Fell and Lowther Hill. It might be expected that Great Dun Fell would be more often in cloud because the summit is slightly higher, 2,780 ft. compared with 2,377 ft. at Lowther Hill, but on the other hand Great Dun Fell is further south and therefore likely to be in cloud less often. So far, therefore, it appears that both places are about as often in cloud. We get the same answer when considering rainfall (a measure of cloud frequency) in that both summits appear to be about equally wet with an annual average of 75 in.

It is interesting to compare these values with those given for hill tops round Glen Nevis*. The values are given as percentage frequency of mist or fog but this is also referred to as the frequency with which the mountains were in cloud.

TABLE III—FREQUENCY OF MIST OR FOG OVER SOME HILL TOPS ROUND GLEN NEVIS
Period: October 25, 1901—February 28, 1902

	Height	0900	1000	1400	2100	Mean
	ft.	*percentage frequency*				
Ben Nevis	4,406	73	70	66	64	67
Sgor-a-Mhaim ...	3,601	54	55	51	42	51
Cairn Dearg	3,348	52	54	50	38	49
Mullach nan Coirean	3,077	46	48	46	36	43
Meall Cumhann ...	2,306	26	27	16	11	20
Mean ...	3,346	50	51	46	38	46

These figures show an increase of cloud with height and that the smallest values occur at 2100, unlike the records from Great Dun Fell and Lowther Hill where the least cloud occurred at 1500. The values for Great Dun Fell and Lowther Hill are more similar to those for the altitudes of 3,077 and 3,348 ft. than for the station at the lower level of 2,306 ft.

The annual number of hours of bright sunshine recorded at Ben Nevis Observatory for the period 1884–1903 was only 736 hr., or 16 per cent. of the total duration of daylight. The percentage varied from 10 in November, December and January, to 22 and 23 in May and June. It would be interesting to record the duration of bright sunshine at Great Dun Fell or Lowther Hill, since in the absence of records we can only give a rough estimate, based on the Ben Nevis records, of about 1,000 hr./yr.

J. GLASSPOOLE

*MOSSMAN, R. C.; The meteorology of Glen Nevis, Appendix to the Meteorology of the Ben Nevis Observatories. Part V. *Trans. roy. Soc. Edinburgh*, **44**, 1910, p. 644.

Thick fog, December 7, 1952

The photograph facing p. 145 was taken at 1800 G.M.T. on Sunday, December 7, 1952, during the thick fog experienced in London. The lamp was 16 yd. away from the camera and the tree 8 yd. One hour later the lamp was invisible but the tree could just be seen against the glow, whilst at 2100 visibility had improved so that the lamp was again visible.

In the photograph it is interesting to note that light scatter from fog particles has rendered the tree trunk less dark than the hedge near the camera.

Rime, December 7, 1952

The photographs in the centre of this magazine were taken in the Royal Botanic Gardens, Kew, in the early afternoon of Sunday, December 7, 1952—that is in the very foggy spell.

The weather was foggy and the sky mostly obscured although the outline of the sun was very occasionally identifiable. The visibility was very variable, between 30 and 100 yd., within the $\frac{1}{4}$ square mile covered. At Kew Observatory the temperature was 29·3°F. at 1330 G.M.T. rising steadily to 31·5°F. by 1400. The ice crystals, however, showed signs of melting at the time of the exposures, and water was dripping from the trees by 1400.

OFFICIAL ANNOUNCEMENT

The Secretary of State for Air has approved the appointment of Professor O. G. Sutton, C.B.E., D.Sc., F.R.S., J.P., at present Dean and Bashforth Professor of Mathematical Physics in the Royal Military College of Science, Shrivenham, to succeed Sir Nelson K. Johnson, K.C.B., D.Sc., A.R.C.S., as Director of the Meteorological Office on the latter's retirement in the autumn of this year.

BOOKS RECEIVED

Onweders, optische verschijnselen enz. in Nederland. Koninklijk Nederlands Meteorologisch Instituut. No. 81, 9½ in. × 6½ in., pp. 56, *Illus.*, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage, 1951. Price: *fl.*2·00.

Upper air data, 1949. Koninklijk Nederlands Meteorologisch Instituut. No. 106A, 12½ in. × 8¾ in., pp. 90, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage, 1951, Price: *fl.*12.00.

ERRATA

FEBRUARY 1953, PAGE 51, bottom line; *for* "Senior Nautical Assistant," *read* "Senior Nautical Officer,".

MARCH 1953, PAGE 87, line 13; *for* "*A century of London weather*," *read* "*A century of London weather*. By W. A. L. Marshall."

WEATHER OF MARCH 1953

Mean pressure was exceptionally high over Europe, the 1020-mb. isobar enclosing almost the whole of this region. The excess of pressure above normal was 10 mb. or more, and reached 18 mb. over the United Kingdom where mean pressure was 1030 mb. The lowest mean pressure, 1001 mb., occurred to the south and east of Greenland, and the mean pressure at the Azores, 1011 mb., was 11 mb. below normal.

Mean temperature was 35° to 40°F. in Scandinavia, 40° to 50°F. in west Europe and 50° to 55°F. in the Mediterranean region, and at most places there was an excess of 2° to 4°F. above normal.

In the British Isles the weather was dry with frequent fog. Mean pressure was exceptionally high and except in the north of Scotland the month was unusually quiet. Sunshine exceeded the average on the whole, and mean temperature was above the average in the north but somewhat below in the south.

Anticyclonic conditions prevailed until the 25th with little or no rain. Fog was widespread in England, Wales and Ireland during the first six days both inland and at some coastal stations, fog or low stratus cloud persisting occasionally all day in some places. This made both sunshine amounts and day temperature very variable. At places with persistent fog very low maxima were registered, for example 32°F. at Watnall on the 1st, 34°F. at Pershore and 35°F. at West Raynham and Cranfield on the 2nd, 33°F. at Mildenhall and 35°F. at Ross-on-Wye on the 3rd and 34°F. at Aberporth on the 4th. On the 7th drier air arrived behind a cold front moving south over the country, and subsequently there was not much persistent fog though it often occurred at night and in the morning. Early morning frost was registered frequently throughout the anticyclonic period, with occasional screen minima of 25°F. or below up to the 16th even in the south. There were many sunny days and maximum temperatures were often above the average, particularly in the west and north. Towards the end of the anticyclonic spell it was notably warm, temperature rising to 70°F. locally on the 24th and 25th. By the 25th absolute drought had lasted for 36 days in many parts of East Anglia and Yorkshire and for 34 days in many areas including London. It was probably the longest drought at this time of year since 1893. On the 25th the anticyclone retreated southward and became less intense and on the 26th a cold front moved south-east across the country ending the drought almost everywhere, though no measurable rain fell locally in north-east England. A changeable westerly type of weather prevailed for the rest of the month. On the 28th a small secondary disturbance moved east across northern England giving heavy rain in Wales and north-west England (4·22 in. at Llangurig, Montgomeryshire, 3·00 in. at Aberangell, Merionethshire, 2·97 in. at Lake Vyrnwy and 2·25 in. at Darwen). On the 29th and 30th another small depression, which formed on an almost stationary front, moved north-east from a position off the south of Ireland; further heavy rain fell in parts of Wales and the Midlands (2·68 in. at Rhondda Water Works, Glamorganshire, 2·40 in. at Treherbert and 2·11 in. at Swansea Water Works, Brecknockshire on the 29th). In other areas rainfall was not heavy; at Tynemouth no rain occurred until the 30th and even then it was only 0·02 in.

The general character of the weather is shown by the following provisional figures.

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	71	16	−0·4	40	−10	117
Scotland	69	16	+1·9	38	−12	130
Northern Ireland ...	65	23	−0·9	19	−14	108

RAINFALL OF MARCH 1953

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	0·43	24	*Glam.*	Cardiff, Penylan ...	1·66	31
Kent	Dover	0·27	13	*Pemb.*	Tenby, The Priory ...	2·45	70
,,	Edenbridge, Falconhurst	0·31	13	*Radnor*	Tyrmynydd	4·88	91
Sussex	Compton, Compton Ho.	0·55	20	*Mont.*	Lake Vyrnwy	5·19	115
,,	Worthing, Beach Ho. Pk.	0·22	11	*Mer.*	Blaenau Festiniog ...	5·31	62
Hants.	Ventnor Cemetery ...	0·37	18	,,	Aberdovey	2·04	61
,,	Southampton, East Pk.	0·54	24	*Carn.*	Llandudno	1·17	50
,,	S. Farnborough ...	0·42	21	*Angl.*	Llanerchymedd ...	0·99	33
Herts.	Royston, Therfield Rec.	0·58	32	*I. Man*	Douglas, Borough Cem.	0·62	21
Bucks.	Slough, Upton	0·37	21	*Wigtown*	Newton Stewart ...	0·53	15
Oxford	Oxford, Radcliffe ...	0·67	41	*Dumf.*	Dumfries, Crichton R.I.	0·48	16
N'hants.	Wellingboro' Swanspool	0·83	46	,,	Eskdalemuir Obsy. ...	0·91	19
Essex	Shoeburyness	0·25	19	*Roxb.*	Crailing	0·27	13
,,	Dovercourt	0·23	15	*Peebles*	Stobo Castle	0·83	20
Suffolk	Lowestoft Sec. School ...	0·30	19	*Berwick*	Marchmont House ...	0·37	14
,,	Bury St. Ed., Westley H.	0·59	31	*E. Loth.*	North Berwick Res. ...	0·26	14
Norfolk	Sandringham Ho. Gdns.	1·05	55	*Midl'n.*	Edinburgh, Blackf'd. H.	0·42	21
Wilts.	Aldbourne	0·77	35	*Lanark*	Hamilton W. W., T'nhill	0·92	33
Dorset	Creech Grange... ...	0·59	21	*Ayr*	Colmonell, Knockdolian	0·29	9
,,	Beaminster, East St. ...	0·67	23	,,	Glen Afton, Ayr San. ...	1·10	26
Devon	Teignmouth, Den Gdns.	0·37	14	*Renfrew*	Greenock, Prospect Hill	2·38	51
,,	Cullompton	1·05	38	*Bute*	Rothesay, Ardencraig ...	1·32	37
,,	Ilfracombe	1·56	54	*Argyll*	Morven (Drimnin) ...	2·34	48
,,	Okehampton	1·74	42	,,	Poltalloch	2·03	53
Cornwall	Bude, School House ...	1·01	41	,,	Inveraray Castle ...	3·74	59
,,	Penzance, Morrab Gdns.	1·26	39	,,	Islay, Eallabus	1·95	51
,,	St. Austell	1·10	32	,,	Tiree	1·33	40
,,	Scilly, Tresco Abbey ...	0·94	36	*Kinross*	Loch Leven Sluice ...	1·19	40
Glos.	Cirencester	1·41	61	*Fife*	Leuchars Airfield ...	0·45	23
Salop	Church Stretton ...	1·26	52	*Perth*	Loch Dhu	2·62	40
,,	Shrewsbury, Monksmore	1·17	70	,,	Crieff, Strathearn Hyd.	1·01	32
Worcs.	Malvern, Free Library...	1·12	58	,,	Pitlochry, Fincastle ...	1·03	37
Warwick	Birmingham, Edgbaston	1·66	87	*Angus*	Montrose, Sunnyside ...	0·39	19
Leics.	Thornton Reservoir ...	1·56	85	*Aberd.*	Braemar	0·65	22
Lincs.	Boston, Skirbeck ...	0·79	51	,,	Dyce, Craibstone ...	0·30	11
,,	Skegness, Marine Gdns.	0·81	49	,,	New Deer School House	0·28	11
Notts.	Mansfield, Carr Bank ...	1·39	67	*Moray*	Gordon Castle	0·50	22
Derby	Buxton, Terrace Slopes	3·01	73	*Nairn*	Nairn, Achareidh ...	0·91	49
Ches.	Bidston Observatory ...	0·89	47	*Inverness*	Loch Ness, Garthbeg ...	2·08	62
,,	Manchester, Ringway...	2·00	89	,,	Glenquoich	5·01	58
Lancs.	Stonyhurst College ...	1·68	46	,,	Fort William, Teviot ...	3·04	45
,,	Squires Gate	0·44	19	,,	Skye, Duntuilm ...	2·37	54
Yorks.	Wakefield, Clarence Pk.	0·75	42	,,	Skye, Broadford ...	3·58	56
,,	Hull, Pearson Park ...	0·54	30	*R. & C.*	Tain (Mayfield) ...	1·30	56
,,	Felixkirk, Mt. St. John...	0·09	5	,,	Inverbroom, Glackour...	3·18	64
,,	York Museum	0·23	14	,,	Achnashellach	3·63	53
,,	Scarborough	0·24	13	*Suth.*	Lochinver, Bank Ho. ...	2·04	54
,,	Middlesbrough... ...	0·13	8	*Caith.*	Wick Airfield	1·26	56
,,	Baldersdale, Hury Res.	0·70	24	*Shetland*	Lerwick Observatory ...	1·82	58
Nor'd.	Newcastle, Leazes Pk....	0·09	4	*Ferm.*	Crom Castle	0·48	15
,,	Bellingham, High Green	0·75	26	*Armagh*	Armagh Observatory ...	0·35	15
,,	Lilburn Tower Gdns. ...	0·19	7	*Down*	Seaforde	0·44	15
Cumb.	Geltsdale	0·60	21	*Antrim*	Aldergrove Airfield ...	0·35	14
,,	Keswick, High Hill ...	0·79	18	,,	Ballymena, Harryville...	0·54	17
,,	Ravenglass, The Grove	0·39	13	*L'derry*	Garvagh, Moneydig ...	0·57	18
Mon.	Abergavenny, Larchfield	1·55	51	,,	Londonderry, Creggan	1·01	32
Glam.	Ystalyfera, Wern House	4·71	88	*Tyrone*	Omagh, Edenfel ...	0·91	29

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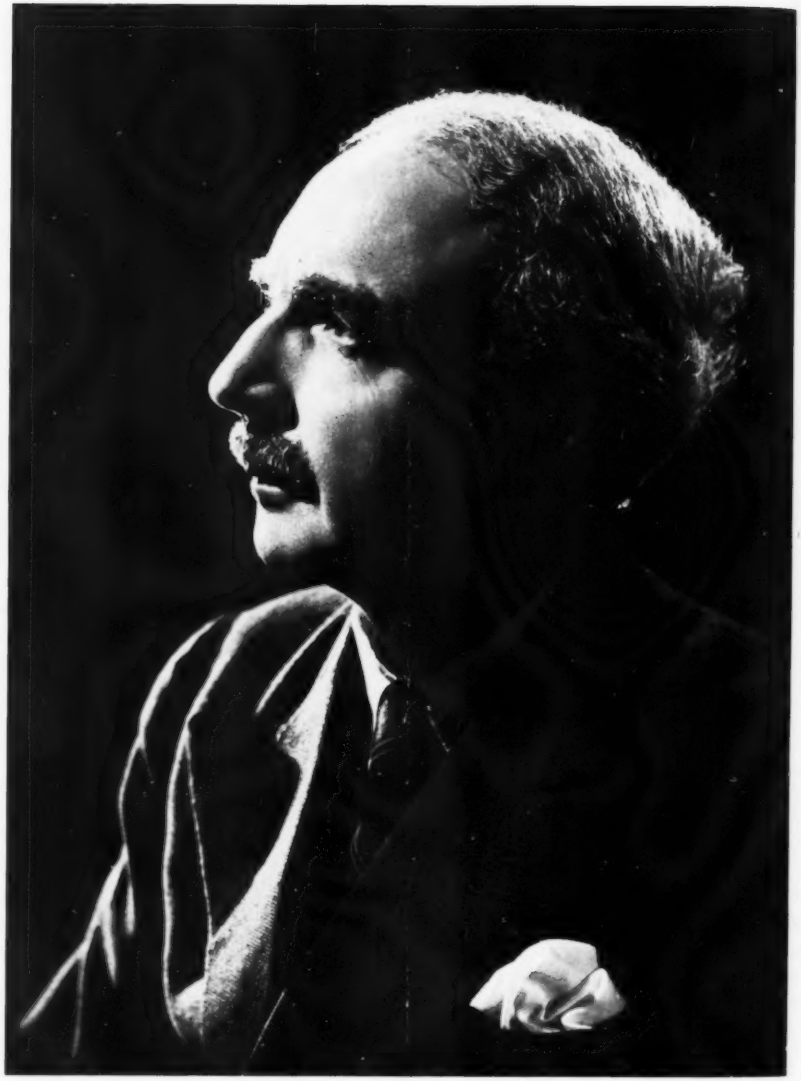
To face p. 161]



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